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Cathodic Protection for Concrete Bridge Deck Restoration

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1/ INTRODUCTION

Cathodic protection is a system for preventing the reinforcing steel in a bridge deck from corroding. It can be applied to a new deck or to a repaired deck to prevent further corrosion.

In the case of a damaged deck, all spalls and delaminations must be cut out and the damaged areas patched in a manner similar to overlay methods of repair. Then cathodic protection is applied to the repaired deck.

Cathodic protection occurs when a direct current (DC) is caused to flow through the concrete, from the deck surface to the rebars. The rebars are thus lowered in potential, made more cathodic, to a potential at which the corrosion reactions cannot occur.

The corrosion of steel is an electrochemical reaction. The reaction can be looked upon as the sum of two half-cell reactions, an anodic reaction and a cathodic reaction. These reactions are as follows:

- anodic - $Fe \leftrightharpoons Fe^{++} + 2e^-$
- cathodic - $1/2\ O_2 + H_2O + 2e^- \leftrightharpoons 2OH^-$

The sum of these reactions are

$$Fe^{++} + 2OH^- \longrightarrow Fe(OH)_2 \text{ (ferrous hydroxide)}$$

The ferrous hydroxide is oxidized to red iron rust or

$$Fe(OH)_3 \cdot (H_2O)_x$$

This rust builds up on the rebar causing pressure on the concrete. When the tensile strength of the concrete is exceeded a spall or delamination results.

Cathodic protection lowers the potential of the rebar to the point where the anodic reaction cannot occur and corrosion stops.

Concrete is a poor conductor of electricity. It has a resistivity in excess of 10 000 ohm/cm. In order to get an even distribution of electrical power across the entire deck area, it is necessary to cover the deck with an electrically conductive asphaltic concrete.

The DC is introduced into this mix at several points by corrosion resistant anodes. The DC is provided by a rectifier which takes the 115 V AC (or 250 V AC) and rectifies it to produce a DC of the required voltage. The flow of current then is from the rectifier to the anodes and into the conductive mix. The conductive mix distributes the power evenly over the deck and the current then flows down through the concrete to the rebars and back to the rectifier. The current is controlled at the required voltage by a zinc-zinc sulphate half-cell which is buried in the deck close to a rebar. This circuit is shown in Figure 1.

The circuit is a relatively "high" current and "low" voltage circuit (approx. 1.3 V and 2-3 A). As a result, the resistance of the conductive mix and the connecting wires must be kept low in order to minimize RI drops. Hence, heavy wire (#6) is often used for individual current feeders and for the ground bus. Too high an RI drop would cause a considerable (and unacceptable) drop in the small voltage applied at the more remote parts of the deck.

The cathodic protection system must be designed for each deck which is chosen for this type of protection. The placement of the anodes depends on the deck geometry so an even distribution of power is obtained. It is important that all reinforcing steel in the deck be electrically continuous. For this reason, several "grounding" locations are chosen at random on the deck and connections are made to the steel, these are then connected to a common ground bus. This bus also connects together sections of the deck which may be separated by expansion joints.

When a DC voltage is impressed on the deck through the cathodic protection system the rebars polarize slowly and build up a negative charge. This polarized charge must be within a certain voltage range in order to protect the steel but not damage the deck. This polarized charge is measured by graphite voltage probes which are sunk in the concrete deck with their upper surface exposed and in contact with the conductive mix. The voltage measurement is made when the applied current is shut off for a moment. All of the voltage probes are connected by individual wires to a control panel under the deck and all measurements are made at this panel.

The polarized charge must be within the range -0.80 to -1.25 V. Voltages numerically less than -0.80 V may not provide protection and greater, numerically, than -1.25 V may cause disbonding over a long period of time. This range is different from that of -0.85 to -1.10 V as recommended in the past. The reason is that this latter range is one measured using a copper-copper sulphate half-cell and here we are using graphite probes (or a carbon half-cell). A full discussion of this is given in the paper "Measurement of Polarized Potentials in Concrete Bridge Decks" by H.J. Fromm, published in Transportation Research Record 692.

2/ DEFINITIONS

Electrically Conductive Asphaltic Concrete - This is a hot mix consisting of stone, sand, coke breeze and asphalt cement. The presence of about 40-45% coke breeze makes the mix electrically conductive. It must be designed to suit the aggregates and coke used at each location.

Coke Breeze - This is a graded coke made from coal and passing the No. 4 sieve. It is obtained from a basic steel manufacturer such as Dofasco or Stelco.

Anodes - These are castings made of Duriron (a high silicon content cast iron) cast in a flat disc shape, 305 mm (12 in.) diameter by 37 mm (1 1/2 in.) thick. They are set into the bridge deck with their upper surface exposed and flush with the bridge deck surface. Their purpose is to take power from the rectifier and distribute it throughout the coke mix. If Durion is not obtainable, graphite disks 254 mm (10 in.) diameter by 37 mm (1 1/2 in.) thick may be used.

Grounds - These are randomly chosen locations on the deck where a rebar is bared and a connecting wire welded to it. These wires are then connected to a common ground wire (ground bus) which is then connected to the negative terminal of the rectifier.

Rectifier - This instrument takes 115 V AC and rectifies it to a low voltage DC. The type of rectifier used is a "potential controlled rectifier" and controls the deck potential by a half-cell buried in the deck.

Half-Cell - This is a "zinc-zinc sulphate" half-cell which is buried in the decks near a rebar to sense its voltage. This cell is connected to the rectifier to control its output to the desired voltage level.

Voltage Probes - These are graphite bars, about 37 mm (1 1/2 in.) square and 150 mm (6 in.) long, which are sunk in the concrete deck with their upper surface exposed and in contact with the underside of the conductive mix. These are connected by wires to jacks in the control panel. These probes sense the voltage distribution across the deck which can be read at the panel.

Control Panel - This panel is situated beside the rectifier and contains the meters by which power to the deck and the polarization (protection) of the deck rebars may be read. The panel is designed for each application of cathodic protection.

3/ SYSTEM DESIGN

3.1/ Anode Placement

It is important that the anodes be distributed along and across the deck so that a uniform distribution of power is the result. The steel in all parts of the deck must be polarized to a potential within the range -0.80 to -1.25 V.

(1) For bridge decks 10 m (33 ft.) or less in width, curb to curb, use a single line of anodes down the center of the deck.
(2) For bridge decks 10 m (33 ft.) to 21 m (70 ft.), use two lines of anodes along the deck, each line spaced 3 m (10 ft.) from each curb.
(3) For bridges greater in width than 21 m (70 ft.), use three lines of anodes. Use two lines of anodes, each spaced 3 m (10 ft.) from each curb, and one line down the center of the deck.
(4) The spacing of the anodes from each other in each line must not exceed 7.6 m (25 ft.). The end anode in each line must not be more than 3 m (10 ft.) from the end of the deck. If the deck is in sections separated by expansion joints or fixed joints, the end anode must not be more than 3 m (10 ft.) from each joint in each section.

Anode placements on decks of different sizes are shown in Figures 2-7. Also shown in some of these diagrams are the placement of voltage probes and half-cells and the ground locations. These will be discussed in the following sections.

Figures 2-7 show how the end distances from each anode string to the end of the deck may be varied from 1.5 to 3 m (5 to 10 ft.) and intermediate anode spacings varied from 6 to 7.6 m (20 to 25 ft.) in order to get an even spacing of anodes on a bridge deck.

Figures 2 to 4 show spacings on narrow bridge decks. Figure 5 shows spacings on a wide bridge deck while Figure 7 shows

spacing on an irregularly-shaped bridge deck. This latter deck has a trumpet-shaped end and requires extra anodes at this end to get an even distribution of current.

In Figure 6, a long deck is illustrated. When a deck exceeds 183 m (600 ft.) in length, two rectifiers should be used. Each rectifier will feed one half of the deck. The rectifiers can be placed at opposite ends of the deck or both at one end, whichever is more convenient. If both rectifiers are at one end of the deck, the rectifier feeding the far end of the deck will have to be operated at a slightly higher voltage to compensate for the RI drop in the longer feeder lines.

No more than four anodes (preferably three) should be connected on each feeder line from the rectifiers. This is the arrangement shown in Figures 2 to 7. In Figure 7, one feeder has five anodes due to the odd deck shape. If some feeder lines are considerably longer than others, this can be compensated for, in order to even out the anode voltages, by placing low value resistors in series with the lines. Each anode must be recessed into the deck and have its upper surface exposed and flush with the bridge deck surface.

3.2/ Ground Locations

Several ground connections are made to the rebars along the entire length of the bridge. This is to ensure that no part of the steel reinforcement is isolated electrically and to prevent any significant voltage drop along the length of the steel structure.

For a deck 30.5 m to 46 m (100 ft. to 150 ft.) in length, five such connections spaced randomly across and along the deck will be sufficient. Longer decks will require proportionately more such locations. At each ground location the wire must be cadwelded to the rebar and must be connected to a #6 stranded bus running the entire length of the bridge deck. This bus is then connected to the ground or negative terminal of the rectifier.

If a deck is divided into sections, each section must be treated as above and the ground bus must be continuous down the entire length of the bridge.

3.3/ Half-Cells

These are zinc-zinc sulphate half-cells and are used to control the rectifier so as to keep the polarized potential on the rebars in the accepted voltage range. These half-cells can fail, so it is recommended that at least three half-cells be included in each deck although only one at a time is used to control the deck. The other two will act as spares. It is recommended that the exact location of each half-cell be carefully recorded in case of a failure. Should this occur, then only that part of the deck need be opened and a new half-cell installed and hooked up to the existing wire in the deck.

Suggested locations for the half-cells are shown in Figures 2-7. It may happen that it is difficult to control the potential of the deck from one half-cell location, then a half-cell in another location can be tried. With several cells in the deck one will be sure to give good results.

At each half-cell location a special structure wire has to be cadwelded to the rebar and run back to the control panel along with the half-cell wire.

3.4/ Voltage Probes

These are graphite probes distributed over the deck to sense both the applied and polarized potentials in the deck. They are recessed in the deck with their upper surface exposed and flush with the bridge deck surface.

These probes are distributed on the deck surface to determine if an even power distribution is accomplished. Their distribution on different decks is shown in Figures 2-7. The problem areas are the corners at the ends of decks or deck slabs, especially in the acute corners of skewed decks. A probe should be placed in this area so that if the voltage is low, corrective measures may be taken at the panel. On narrow decks with one line of

anodes, sometimes the potential close to the curbs is low, so one or more probes should be placed in these areas. Probes should also be placed close to the line of anodes to detect voltage above the recommended range.

3.5/ Electrical Connections

All deck elements, anodes, grounds, half-cells and probes shall be connected by wires which run in slits cut in the deck to the nearest curb. There the wires will either be joined to bus wires or themselves be run along the curb to the end of the deck. There they will pass through a 102 mm (4 in.) hole in the deck into a 76 mm (3 in.) plastic conduit and be lead to the control panel and rectifier. All details of these wires, connections, etc. are given in the following section, "Construction".

4/ CONSTRUCTION

Specifications for all of the materials used for cathodic protection are listed in the next section, "Specifications".

4.1/ Anodes

Mark out all anode locations on the deck according to the design. Each anode has to be set in a recess 50 mm (2 in.) deep. At each anode location use a pachometer (cover meter) to locate the rebars. The anode location may be shifted up to 150 mm (6 in.) in any direction so that the minimum number of rebars will have to be cut in making the recess. If the concrete cover is greater than 50 mm (2 in.), then the anodes will be placed according to design. Anode recesses can be cut by any of the following methods:

(1) Use a 330 mm (13 in.) Kontax Scabbler to drill the recess. As rebars are encountered, stop drilling and cut them out flush with the hole wall sides and resume drilling to 50 mm (2 in.).

(2) Use a 330 mm (13 in.) core drill and cut out the concrete with a nominal 30 lb. jackhammer. Remove any exposed rebars and make the hole bottom as smooth as possible at a depth of 50 mm (2 in.).

(3) Using a concrete saw, make four cuts to a depth of 50 mm (2 in.) as shown in Figure 8 and remove the center cover with a nominal 30 lb. jackhammer. With a torch, cut out all exposed rebars flush with the recess walls.

After the anode recesses have been prepared, any exposed rebars in the bottom of the recesses or cut rebar ends must be painted with a thick layer of epoxy asbestos paste (see Section 6, "Specifications"). Using a concrete saw equipped with a 6 mm (1/4 in.) thick dry blade, cut a slit in the deck 6 mm (1/4 in.) wide and 13 mm (1/2 in.) deep from the anode recess to the curb. The anode connecting wire will be run in this slit to the curb. Extend the slit from where the saw has to stop to within 25 mm (1 in.) of the curb.

After the epoxy-asbestos paste covering the exposed rebars and rebar ends has set, spread a layer of epoxy-asbestos paste 13 mm (1/2 in.) thick over the bottom of the recess. Lay the anode in the recess on the paste and its connecting wire in the slit and run the wire to the curb. A few small stones placed in the paste will prevent the anode from sinking too deep into the paste. Adjust the anode and paste so the surface of the anode is flush with the deck surface (see Figure 9).

When the epoxy asbestos paste has set, fill in the area between the anode and recess side with a sand-cement paste. If saw cuts were used to form the recess, fill in the cuts with epoxy-asbestos paste.

Ensure the connecting wire is pressed down in the slit so it will not be damaged by traffic on the deck. Fill slit with epoxy paste. Cover the surface of the anode with adhesive tape to protect it until the deck is paved, at which time the tape will be removed.

4.2/ Grounds

Mark each ground location on the deck according to the design. At each location, use a pachometer (cover meter) to locate a rebar. Drill a 100 mm (4 in.) hole through the deck to the rebar, remove the core to bare the upper surface of the rebar. Clean an area of the rebar free of corrosion deposits. Cut a slit from this hole to the curb, (as described in Section 4.1, "Anodes") for the ground wire to run in from the rebar to the curb.

Place a white ground wire in this slit and cadweld it to the rebar. When the weld is cool, cover the entire weld and rebar with silicon seal paste and let it set. Fill the hole with concrete and level with the deck surface.

4.3/ Half-Cells

Locate the half-cell locations on the deck as shown in the design. Locate a rebar with a pachometer (cover meter) at the designed location and cut a recess 250 x 250 mm

(10 x 10 in.) with the concrete saw. With a 30 lb jackhammer remove the concrete down to the rebar. Cut a slit from this recess to the curb as described in Section 4.1, "Anodes" but with the following change: make the slit 20 mm (3/4 in.) deep since two wires must run in this slit from the recess to the curb.

At one end of the rebar clean a portion of the metal free of corrosion deposits and cadweld a white special ground wire to it. Insulate this weld with silicon seal paste as described under "Grounds".

Coat the exposed rebar with cement grout and let the grout dry. Then place the zinc-zinc sulphate half-cell against the grout coating and run its wire and the special ground wire together in the slit to the curb (Figure 10). Fill the half-cell recess with concrete and the saw cuts with epoxy-asbestos paste.

4.4/ Probes

Mark each probe location on the deck as shown in the design. Using a pachometer, locate the rebars and mark the probe location midway between two rebars.

Cut two slits with the concrete saw about 100 mm (4 in.) apart and longer than the length of the probe. Cut the slits about 50 mm (2 in.) deep. Knock out the concrete between the two slits with a 30 lb. jackhammer, this forms the probe recess. Cut a slit from this recess to the curb as described in Section 4.1, "Anodes" (Figure 11).

Place some sand-cement in the recess and set in the probe and run its wire in the slit to the curb. Adjust the cement mixture so that the surface of the probe is flush with the bridge deck. When the cement has set, clean off the surface of the probe and protect it with adhesive tape until the deck is to be paved (Figure 11).

NOTE: If the bridge deck has expansion joints or fixed joints which separate the deck into sections, the electric wires of the system must bypass these joints. This is done by drilling holes through the deck, one on either side of the joint. The cable of wires then passes down and around the joint and back up on the other side, leaving an expansion loop. In cases where a large haunch has to be bypassed, conduit should be used.

4.5/ Control Panel and Rectifier

These are to be mounted on the wing wall or abutment under the bridge. They must never be mounted on the diaphragm between the beams because of excessive vibration. The conduit connecting the panel with the bridge deck shall be 76 mm (3 in.) I.D. plastic conduit. This is specified in order to resist vandalism which has occurred under the bridge decks. The conduit shall be fastened to the abutment with either galvanized iron or aluminum conduit straps. Mount the pilot light on conduit pipe and place it so it is above the bridge deck where it may be easily seen by the patrolman when passing. If there is danger of vandalism, mount the pilot light directly on the rectifier.

It is important that the conduit should enter the control panel from the bottom, as shown in Figure 12. There is always some water or moisture seepage from the deck into the conduit and this would cause corrosion of the panel fittings. The L-B's below the level of the panel have 6 mm (1/4 in.) holes drilled in their bottom covers so that any drainage water which collects may drain out.

4.6/ Electrical Connections

Prior to the application of cathodic protection to the deck, a 115 V (or 250 V) line should be run in to the side of the bridge deck and terminate in an approved service entrance box. This must be provided with twin grounds as shown in Figure 12. The box must be located on the bridge abutment as shown in the design, either on the side wing wall or under the deck on the abutment. It must never be installed on the diaphragm.

4.6.1/ Anodes

Check the resistance between each anode lead wire and a ground wire using an AC ohmmeter. The resistance value should be high, if a low value is obtained the anode may be shorting to a rebar. If this is the case, the anode must be removed and the shorting metal insulated.

(Note: A regular type ohmmeter cannot be used since a potential exists in the concrete deck due to reaction between the concrete and the rebar.)

Connect the anodes to the feed wires as shown in the design. Usually, three anodes are connected to each feed wire. Sometimes, however, four, or even five in special circumstances, are connected to one feeder as shown in Figure 7. Feed wires for very short runs can be #10 gauge but #6 gauge is usually used for this purpose. Connect each anode to the feed wire by a cadweld joint. When the joints are cool, cover the joint completely up to the insulation with silicon seal paste. Let the paste harden then wrap the joint with plastic electrical tape to make a waterproof joint. All feed wires shall have black TWU (underground) insulation. Each feed wire shall be carefully numbered with the number shown in the design. It shall then be run along the deck at the curb and down through the conduit to the control panel.

4.6.2/ Grounds

Connect each white ground wire to the #6 gauge ground bus wire. Make connections and insulate as described previously in Section 4.1, "Anodes". Run the ground bus to the end of the deck and down through the conduit to the control panel.

4.6.3/ Probes

Connect each red probe wire to another #10 red wire using an in-line connector. Crimp the connection, heat with a torch and run in solder. When cool, cover the joint with silicon seal paste and let the paste harden. Wrap joint with plastic electrical tape to make a waterproof joint. Number the wire with the probe number shown in the design and run the wire along the curb to the control panel.

4.6.4/ Half-Cells

Connect the green half-cell wire and the white special ground wire at each half-cell location, respectively, to a #10 green and #10 white wire at the curb. Make each joint and insulate as described above under "Probes". Twist or tape the two wires together, number them as shown on the design, and run the wires to the control panel.

(Note - Re wire colors: All anode wires and anode feed wires shall be black and all ground wires and ground bus wires shall be white TWU stranded copper wire. The red wires for the probes and the green wires for the half-cells may be other distinctive colors if these are not available at the time.)

4.6.5/ Panel Wiring

The panel is to be wired with #12 gauge stranded copper wire as shown in Figure 13. Connect each anode feeder wire to the terminal strip and label with its number. Connect the ground bus to the terminal strip.

Connect each probe wire to the terminal strip connection corresponding in number to the probe wire number. The half-cell wires are to be taken directly to the panel jacks labelled for half-cells. Connect half-cell #1's green wire to #1 panel jack.

Leave the special white ground wire, which is taped to it, unconnected. Do the same for the other half-cell wires and connect them to the panel jacks. Decide which half-cell will be used first for control. Run a green wire from the jack where the half-cell is connected to the rectifier. Connect a white wire to the special ground wire of the half-cell and run it to the rectifier. On the rectifier panel, connect the white special ground to the structure terminal and the green half-cell wire to the half-cell terminal. Connect the positive (+) and negative (-) terminals of the rectifier to the (+) and (-) wires of the control panel.

Connect the rectifier to the 115 V AC source. Also connect the duplex receptacle of the control panel to the 115 V AC source. Wire in the pilot light on the bridge deck to the rectifier. This completes the wiring of the cathodic protection system.

4.7/ Deck, Final Preparations

After all of the electrical wiring has been done on the bridge deck and all wires have been led to the control panel, the wires along the curb must be cabled. Tie these wires together with plastic cable ties and ramset the ties to the deck to hold the cable in place.

Lay and fasten 2 x 4 in. planks on the deck along the cable, about 50 mm (2 in.) out from the curb to act as a form. Fill the space between the form and the curb with concrete to encase the cable. This fillet will usually be about 50 mm x 50 mm (2 x 2 in.). On larger decks with more wiring it may be necessary to increase the size of this fillet.

Inspect the entire deck surface to see if any exposed iron, such as rebar ends or tie wires are on the surface. If any are detected, cover them with epoxy-asbestos paste. Any exposed iron will cause a short circuit and completely negate the system.

Remove the 2 x 4 forms from the deck fillet and blow the deck clear of all debris.

4.8/ Paving of Bridge Deck

Prior to paving, lay 2 x 6 in. planks on the deck along all metal expansion joints or fixed joints in order to prevent the conductive mix from touching the iron. If large rectangular metal bridge drains are present, protect these also with 2 x 6 in. planks. Figure 14 shows an expansion joint with 2 x 6 in. planks laid alongside of it for insulation. If the drains are circular pipes, pave up to them and remove the conductive mix after compaction. Remove the adhesive tape from the anodes and the probes and brush them with a stiff wire brush.

Apply the conductive mix with a paver and compact in the normal manner to a depth of 37 mm (1 1/2 in.). If the bridge drains were small circular drains, cut the compacted conductive mix away from the drains with a shovel. Remove the planks from the expansion joints. Fill in the spaces around the bridge drains and expansion joints with the regular surfacing mix and tamp it down. The normal surfacing mix is then applied over the entire deck and compacted to a depth of 37 mm (1 1/2 in.).

5/ ADJUSTING THE CATHODIC PROTECTION SYSTEM

5.1/ Instruments Required

AC Ohmmeter - An AC ohmmeter, Vibroground or Megger is required to measure resistance values in the deck. The meter must be able to measure down to 0.10 ohm. A regular battery-operated DC ohmmeter cannot be used since a potential of about 0.2 V exists between the concrete and the rebars.

Electronic Voltmeter - A multimeter with a minimum of 11 megohms input impedance must be used to measure half-cell and deck potentials.

5.2/ Adjustments

The adjustments should be done by the Cathodic Protection Engineer.

Remove each anode feeder from the terminal and measure the resistance between each one and the ground terminal on the panel. Record each value. Use an AC ohmmeter to measure the resistance. Reconnect the anode feeder wires to the terminal strip.

These values are the ground bed resistance for each anode group and they should be similar in value, around 1-2 ohms.

Use the AC ohmmeter to measure the total ground bed resistance between the ground terminal and the positive lead. Using an electronic voltmeter of 11 megohms or greater impedance, measure and record the voltage between each half-cell and ground. These should be in the range 0.4 to 0.7 V for zinc cells.

Turn on the rectifier and adjust its output to 1.5 V DC according to the manufacturer's directions. Make sure a jumper is fixed between the interruptor binding posts. Throw the control panel switch to "ON" to energize the system. The voltage applied to the anodes and the current strength will be indicated on the panel meters. It will take some time before the system is polarized to equilibrium. As equilibrium is approached, the current strength will drop. Some systems take two to three days for the full equilibrium potential to build up on the rebars. The voltage applied will always be a few tenths of a volt higher than the equilibrium polarized potential.

The build up of polarized potential may be observed by flipping the panel switch to "OFF" and reading the panel voltmeter. The switch meter then indicates the potential polarized on the rebars. Immediately return the panel switch to "ON".

The distribution of power in the deck can be read by plugging an electronic voltmeter into the various probe jacks and reading the potential between each jack and ground. Polarized voltage in the area of each probe can be read by flipping the panel switch momentarily to "OFF".

When the polarized voltage in the deck as indicated by the panel meter approaches the range 0.80 to 1.25 V, read the polarized potential distribution in the deck as indicated by the voltage probes. Adjust the applied voltage at the rectifier so that the polarized potential in all parts of the deck falls within the range 0.80 to 1.25 V.

If some areas are below this range while others are at the top of the range, place some very low value power resistors in the anode feeder lines of those which are running high. This should even out the power distribution.

Finally, adjust the amplight using the rectifier manufacturer's directions so that it goes "ON" if the applied voltage falls below the protecting level of 0.8.V.

6/ MATERIAL SPECIFICATIONS

Connecting Wire - All wire shall be stranded copper wire with TWU insulation. The wire gauge and insulation color shall be as follows:

- ground bus, #6 white
- anode feeders, #6 black
- ground connecting wires on deck, #10 white
- probe wires, #10 red (or approved color change)
- half-cell wires, #10 Green (or approved color change)
- special grounds at half-cells, #10 white

Silicon Seal Paste - As supplied by General Electric Company.

Epoxy-Asbestos Paste - This is prepared from a commercial thin epoxy resin and curing agent. After mixing the resin and curing agent, asbestos fibres are stirred in to form a relatively thick paste.

Anodes - The anodes shall be made from high silicon content cast iron, "Duriron". They shall be 305 mm (12 in.) in diameter and 37 mm (1 1/2 in.) thick. Each anode shall have a connecting wire attached to it by the supplier. The wire shall be #10 gauge stranded coper wire with black TWU insulation. The wire shall be leaded in a hole in the anode and the hole sealed with a plastic or asphaltic compound. The wire shall be specified of a length to reach the curb. If Durion is not available, graphite anodes may be used. These anodes are usually 254 mm (10 in.) in diameter and 37 mm (1 1/2 in.) thick. The same wire lead as above must be used and fastened in a hole of the anode with a mechanical seal and the hole filled with a plastic or asphaltic compound.

Voltage Probes - These shall be made from a square bar of graphite. Each probe shall be 37 mm x 37 mm by 150 mm long. (1 1/2 in. x 1 1/2 in. x 6 in.). A lead wire, #10 gauge

stranded copper wire, TWU red insulation, shall be fitted into a hole in one end (37 x 37 mm face) with a mechanical seal and the hole filled as in Section 4.1, "Anodes". The wire shall be of sufficient length to reach the curb.

Control Panel - The panel shall be constructed from materials specified below according to the design shown in Figure 13. The number of half-cell jacks and voltage probe jacks shall vary with the requirements of each installation.

All control panel wire shall be 12 AWG stranded copper insulated wire.

Control Panel Box - Shall be as supplied by Electrosonic (Toronto), Hammond catalogue number 1418N4E8 or approved equal. The box shall be made from heavy steel with an internal panel on which to mount the instruments and switches. The box shall be approximately 24 in. high by 20 in. wide by 8 in. deep. The bottom of the box shall have a hole for the 3 in. PVC conduit adaptor. The side of the box shall have a hole for the conduit to connect to the rectifier.

Terminal strips - Shall be as supplied by Electrosonic (Toronto) Cinch-Jones catalogue number 12-540 or approved equal. The terminal strips shall have 12 or more connections each as determined by circuit design.

Voltmeter (for control panel) - Shall be as supplied by Electrosonic (Toronto) GE catalogue number L531 MTMT or approved equal. The voltmeter shall be a 10 V self-contained meter.

Ammeter (for control panel) - Shall be as supplied by Electrosonic (Toronto) GE catalogue number L530 LSLS or approved equal. The ammeter shall be a 5 A self-contained meter.

On-Off Switch - Shall be as supplied by Electrosonic (Toronto) JBT catalogue number 4222S or approved equal.

5-Way Binding P sts (RED) - Shall be as supplied by Electrosonic (Toronto), Si or catalogue number DF31 RD or approved equal.

5-Way Binding Posts (BLACK) - Shall be as supplied by Electrosonic (Toronto), Superior catalogue number DF31 BC or approved equal.

Rectifier - Shall be Goodall Rectifier TPAYCA84GKNS. If substitution is desired, it must be approved in advance of ordering by the Cathodic Protection Officer. The rectifier shall be a standard auto-volt rectifier designed for cathodic protection installations.

The rectifier shall have the following properties:

- Line:	120 V AC 60 cycles
- Output:	0-8 V DC continuously variable from an auto transformer current, 4 A maximum
- Bridge:	center tap, single phase, full wave
- Rectifier Stack:	silicon
- Protection:	lightning protection on input and output
- Circuit Meters:	panel-mounted voltmeter and ammeter
- Mounting:	combination pole or wall mount
- Case:	small arms proof, hasp for padlock
- Amplight:	current-activated light for remote mounting

These are available from Corrosion Service Co. Ltd., 10 Price Street, Toronto, or Interprovincial Corrosion Co., Burlington.

The pilot light of the rectifier is mounted on the rectifier or above the bridge deck to warn the patrolman if the system malfunctions. Its location depends on the possibility of vandalism to the light. If a large bridge is to be protected, which will require more than 4 A, it will be necessary to provide a rectifier of greater current rating.

Conductive Asphaltic Concrete Mix

This mix is essentially a HL-4 mix containing Coke Breeze to make it conduct electric current. The composition of the mix will be approximately:

- HL-4 stone: 40% wt.
- HL-4 sand: 15% wt.
- coke breeze: 45% wt.
- asphalt cement: 15% wt. of mix.

The coke is very porous, hence the high asphalt content. The asphalt cement may be either 85/100 or 150/200, whichever is being used on the contract.

Conductive Mix Specifications

Marshall Stability, (N):	-	4450 minimum
Voids, (% vol.):	-	6 maximum
Resistivity, (ohm/cm):	-	3 maximum

Coke Breeze

A graded, crushed material made from coal (not from petroleum); all passing a No. 3 sieve with the following approximate grading:

Sieve No.	% wt. Passing
3	100
4	92
16	63
50	22
100	8
200	4

Mix Design

It is recommended that the mix design be done at Downsview Lab where instruments and apparatus for measuring resistivity are available.

7/ MAINTENANCE OF THE CATHODIC PROTECTION SYSTEM

1. After the system has been set up and placed in operation, it should be checked weekly for the first month to ensure the initial settings were correct. After smooth operation has been achieved, monthly checks should be sufficient.

2. The local patrolman will observe the pilot light on the bridge daily and show in his daily report if the light is OFF. If the light is ON he should notify the Maintenance Supervisor so that an electrician can be dispatched to determine the nature of the problem.

3. Monthly (Weekly) Inspection of System.
   The form shown in Figure 15 will be filled out when the system is inspected. The inspector will make the following checks
   a/ Note panel meter current.
   b/ Note panel meter volts, with system operating. Open panel switch and note OFF volts on meter. Close switch.
   c/ Attach "ground" lead of electronic, high-impedance meter to "ground" terminal on panel.
   d/ Attach positive lead of meter to each half-cell binding post in turn and record ON and OFF volts, flipping the switch to get the OFF volts. If zinc half-cells are used in the bridge deck, their voltage will be negative and the meter polarity must be reversed to get a reading. Record such voltage as negative.
   e/ Record the ON and OFF voltages of each probe binding post in turn. These voltages should always be positive.

All voltage probes should show an OFF voltage in the range 0.80 to 1.25 V. If the probe voltages are low the DC output of the rectifier must be raised according to the manufacturer's directions to place all probes in the specified range. If all probes cannot be kept in the specified range, contact the Cathodic Protection Engineer at Downsview.

4. If the pilot light is OUT proceed as follows:
   a/ Check AC supply with meter. If AC is on, pilot light may be burned out.
   b/ If the pilot light is not out but fails to come on within the AC, the problem is in the rectifier.
   c/ Depress the rectifier panel meter switch to see if power is being applied to the deck. If the applied DC is below 0.8V., this is the cause of the pilot light being out. Reset the screw on the printed circuit card to give 2.0V (or whatever was previously determined as the correct DC output). The light should now come on and the bridge circuit operate as designed. If no power is being applied, either the AC input or DC output fuse may be blown. If both fuses are OK, the problem lies in the printed circuit card. Turn off the rectifier, remove the old card and replace with a new card. Turn on the rectifier and adjust the card as described in the rectifier instructions to give the desired output. If all these fail, call the rectifier supplier for advice.

5. At least every six months the setting in the rectifier for the pilot light should be checked. This light should be set to turn off if the applied DC falls below 0.8V.

6. Since all bridges have deicing salt applied during winter, the locks on the three boxes (service entrance, control panel and rectifier) should be covered with plastic during this season. If not covered, the salt corrodes the inside of the locks and they cannot be opened.

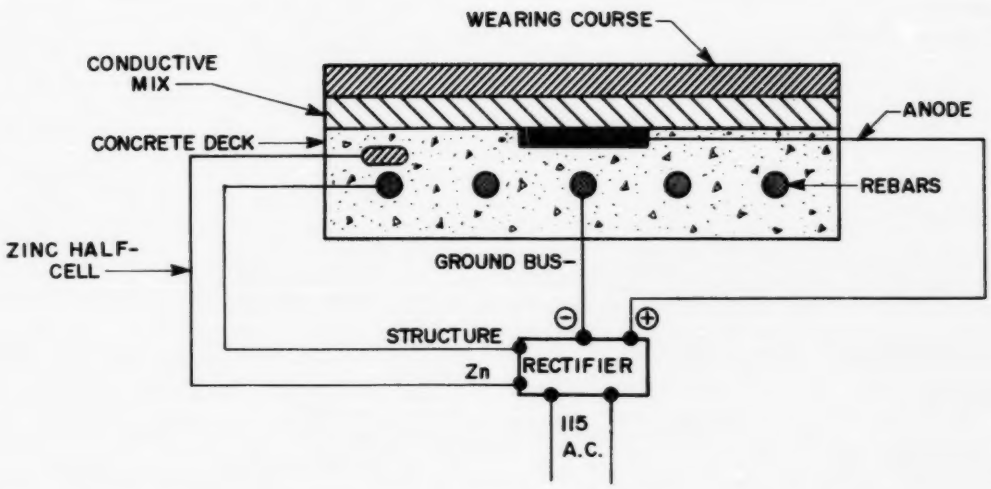


Figure 1/ Cathodic Protection Circuit

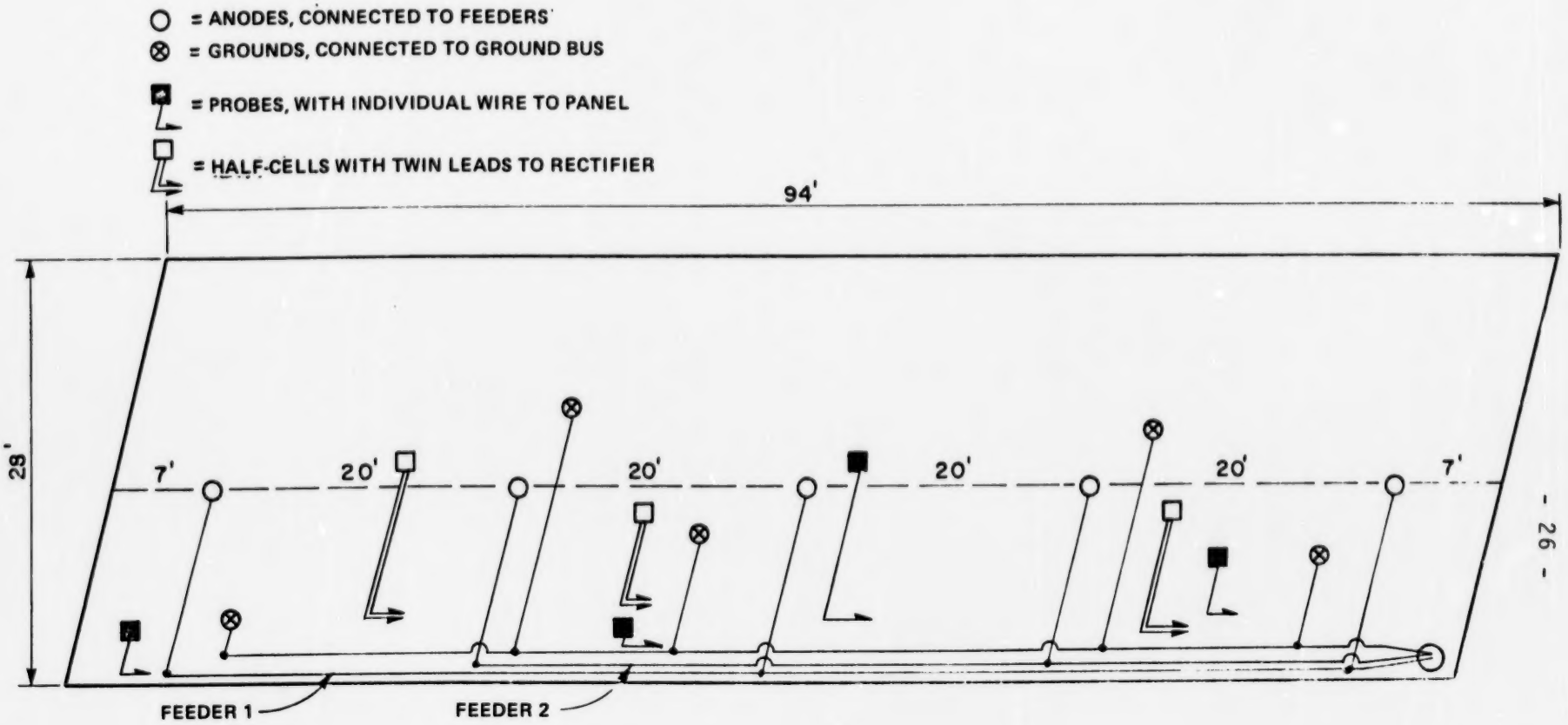


Figure 2/ Short, Narrow Bridge Showing Anode Spacing, Random Placement of Grounds and Probe and Half-Cell Locations.

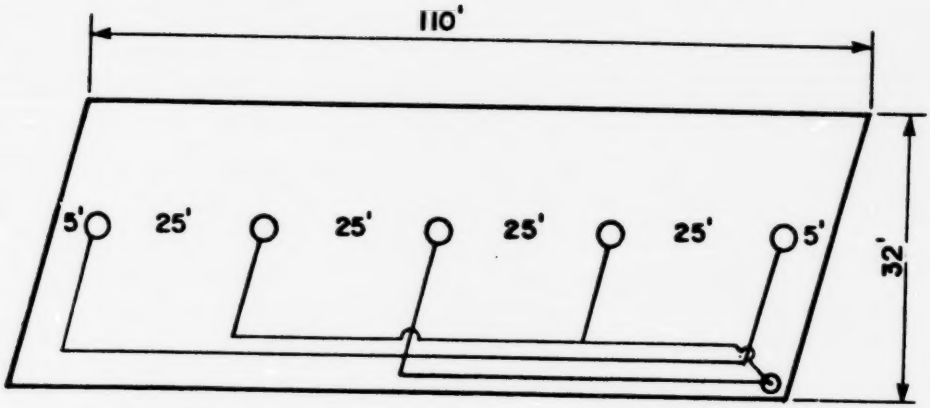


Figure 3/ Narrow Bridge Showing Anode Placement and Wiring Probes, Half-Cells and Grounds not Shown.Similar to Figure 1 .

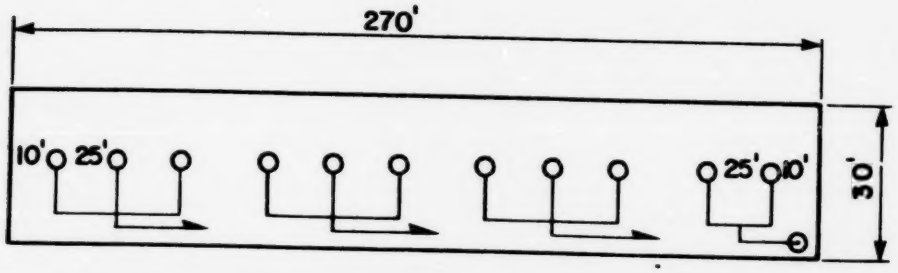


Figure 4/ Long,Narrow Bridge Showing Anode Placement in Groups of Three. Other Components Not Shown.

Figure 5/ Wide Bridge Showing Two Lines of Anodes and, Probe, Half-Cell and Ground Placement

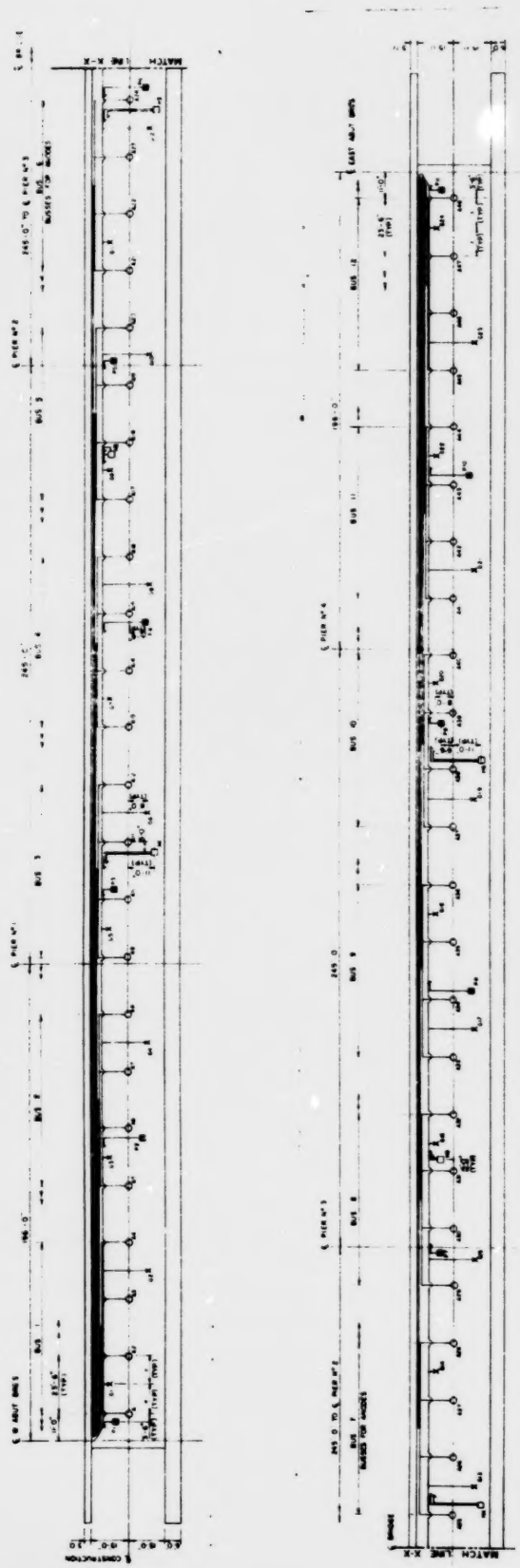
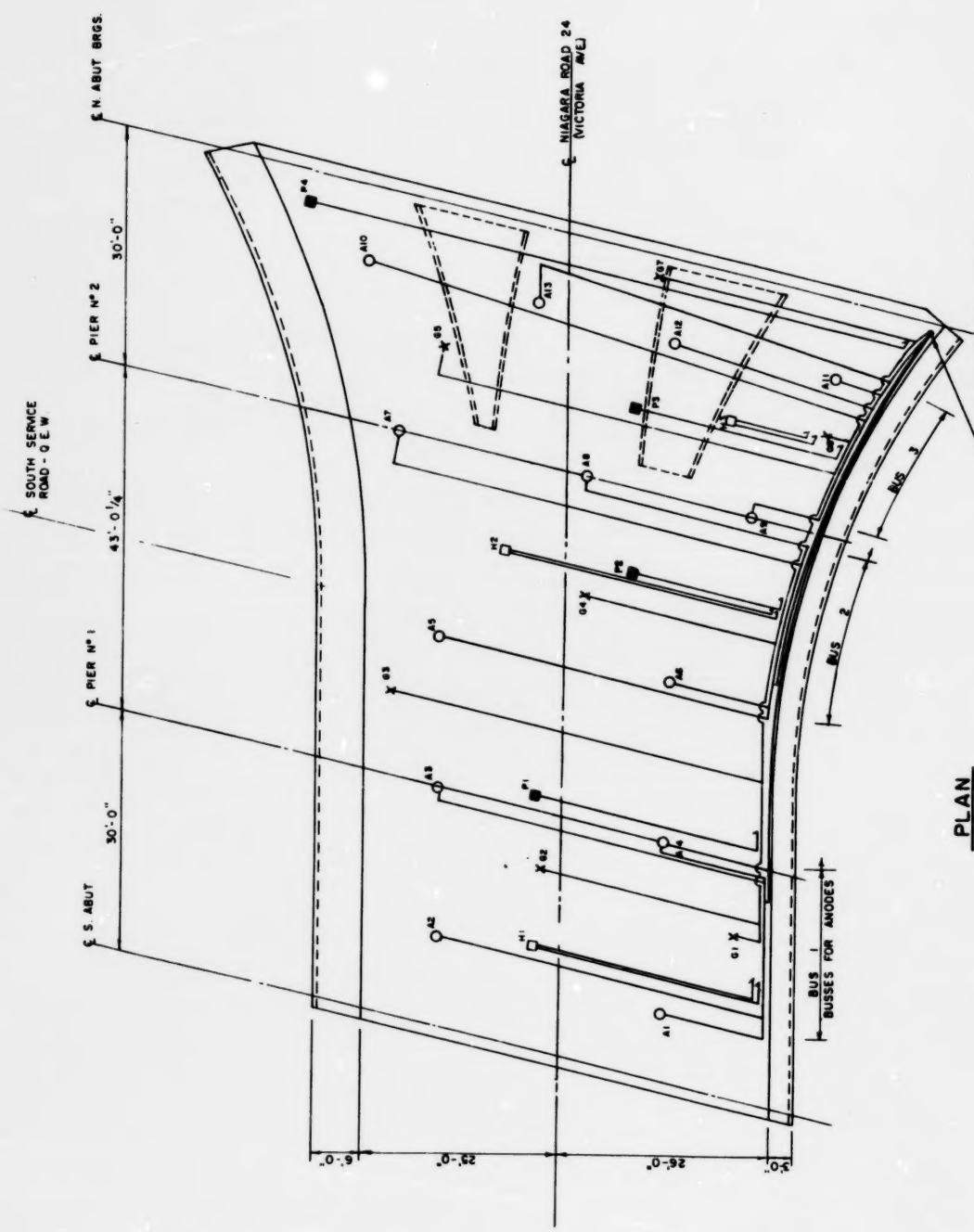


Figure 6/ Long Narrow Bridge Showing Anode, Probe, Half-Cell and Ground Placement



PLAN
SCALE 1"=10'-0"

Figure 7/ Irregularly Shaped Bridge Showing Anode, Probe, Half-Cell and Ground Placement

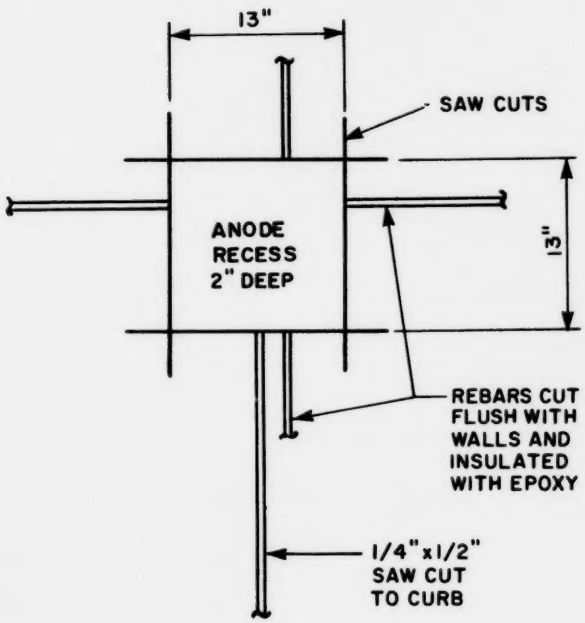


Figure 8/ Anode Recess

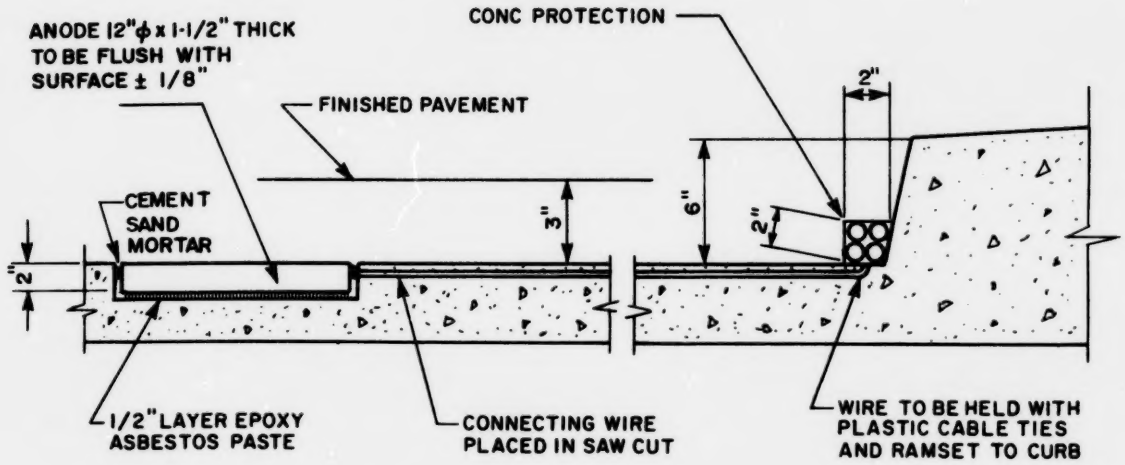


Figure 9/ Anode in Recess and Wire Cable at Curb

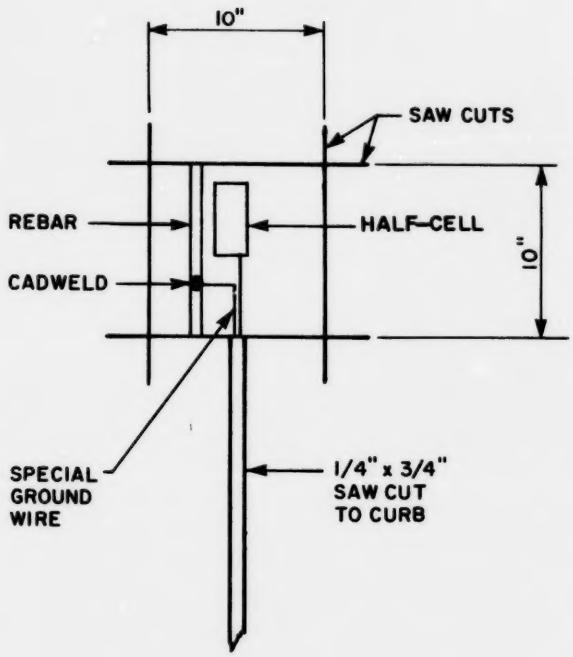


Figure 10/ Half-Cell Recess

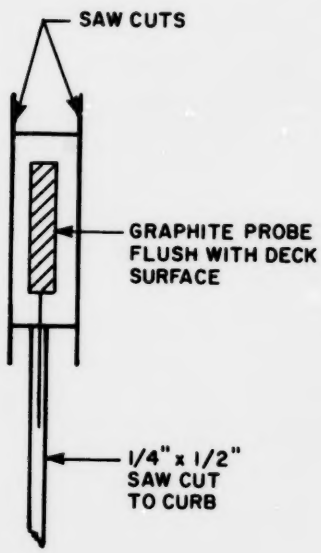


Figure 11/ Probe Recess

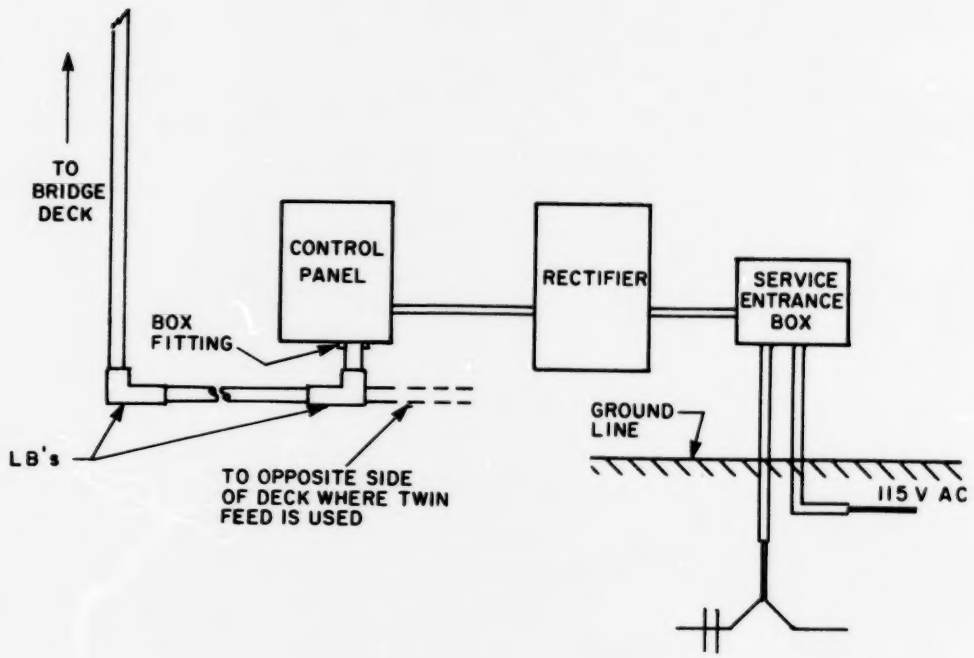
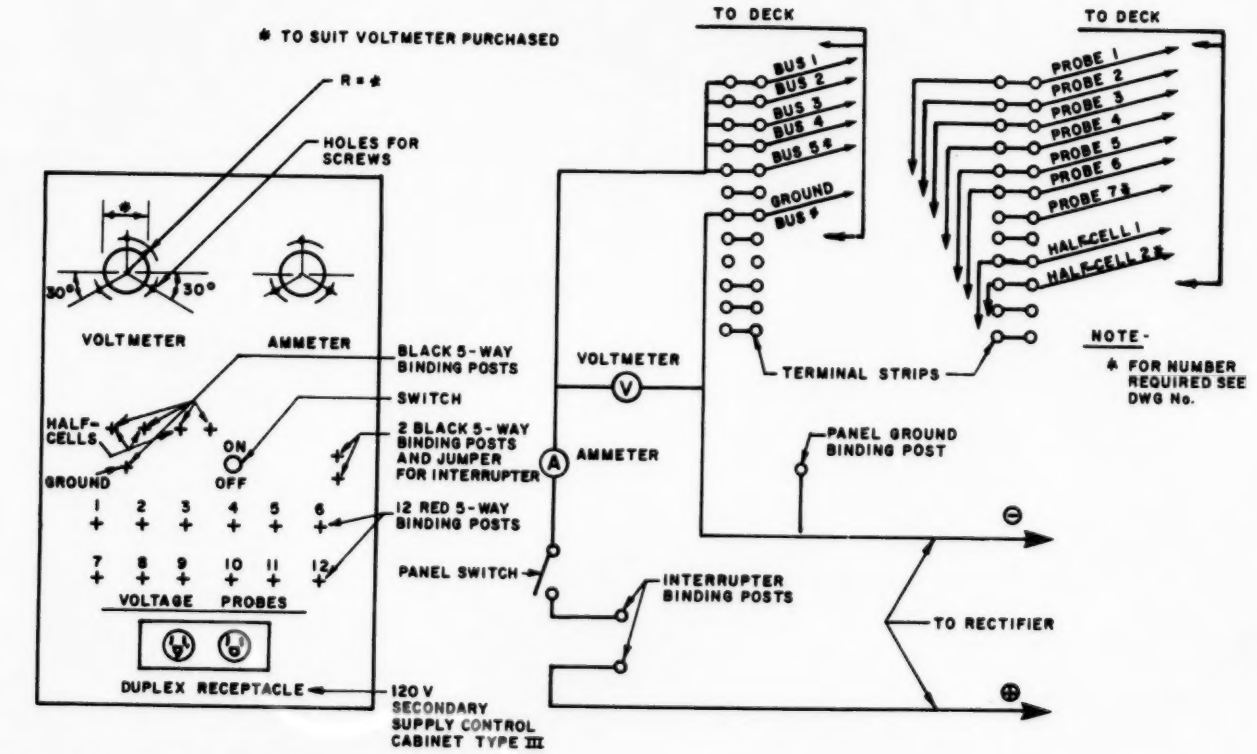


Figure 12/ Arrangement of Electric Boxes, Conduit



FRONT VIEW OF CONTROL PANEL

CONTROL PANEL WIRING SHALL BE 12 AWG STRANDED COPPER INSULATED WIRE

PANEL WIRING

Figure 13/ Front View of Control Panel and Panel Wiring

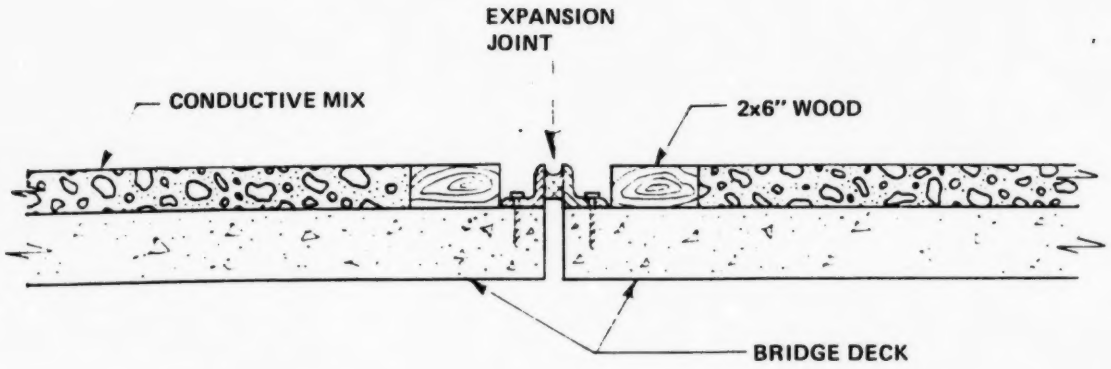


Figure 14/ Insulating Metal Expansion Joints from Conductive Mix

Figure 15/ Inspection Report

Cathodic Protection System

Bridge: - _____ Date: - _____

Panel Current _____ amps

Panel Volts ON: - _____ OFF: - _____

Half-Cell, Volts	ON	OFF
1		
2		
3		
4		
5		

Probe, Volts	ON	OFF
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Comments:

Adjustments Made: